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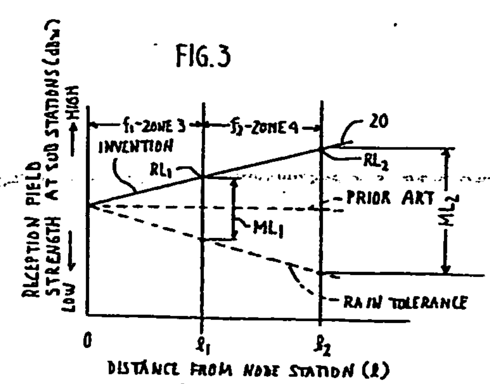
(54) Radio communications system with reduced interference.

(57) A radio communications system has a node station centrally located in a covering area and a plurality of remote substations. The system comprises a plurality of transceivers in the node station, and a plurality of substation transceivers respectively located in the substations corresponding respectively to the node station transceivers to establish a plurality of pairs of two-way radio links therebetween. The covering area is divided into a plurality of concentric zones, each of the zones being assigned a pair of particular frequencies or a pair of particular polarization planes. Each zone has one or more substations. Transmission power level of each of the node station transceivers and each of the substation transceivers is adjusted so that fine-weather reception field strength at each end of those radio links having a greater length is greater than fine-weather reception field strength at each end of those radio links having a smaller length, there being a linear relationship between the field strength at each end of each radio link and the length thereof. The minimum azimuth angular spacing between adjacent substations can be reduced by a factor of 1/4 to allow a greater number of substations to be accommodated in the system.

FIG.3



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TITLE MODIFIED
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TITLE OF THE INVENTION

"Radio Communications System with Reduced D/U Ratio Variations"

BACKGROUND OF THE INVENTION

The present invention relates to a radio communications system in which a plurality of transceivers are located centrally in a node station on the one hand and a plurality of corresponding transceivers are located randomly in remote substations on the other to establish two-way radio links between the node station and substations.

The quality of the sub-to-node station radio link is determined by interference between adjacent substations and this intererence is quantitatively evaluated by the ratio of a signal which is transmitted from a desired substation and received at the main-lobe sensitivity of a node-station receiving parabolic antenna to a signal which is transmitted by an undesired substation and is usually received at a side-lobe sensitivity of the antenna. This desired-to-undesired (D/U) ratio is usually controlled to within a prescribed tolerable range. However, rainfalls cause different attenuation in the main-lobe and side-lobe transmission paths. In particular, if the desired and undesired substations are spaced apart a great distance, the main-lobe and side-lobe paths have a significantly different rainfall attenuation which can result in a deterioration of the D/U ratio.

According to prior art radio communications systems, a single frequency pair is assigned to the node station and all substations of the system and adjacent substations are

usually spaced apart so that they subtend at the node station with a minimum azimuth angle of 90 to 120 degrees to satisfy the required D/U ratio. If an additional substation is to be located within this azimuth angle, the usual practice is to assign a different frequency pair to the additional radio links to maintain the D/U ratio within the required range. However, it is desired to increase the number of substations that can be accommodated within a given covering area.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a radio communications system which can accommodate a greater number of substations to increase radio communications links in economical manner.

According to the present invention, a radio communications system has a node station centrally located in a covering area and a plurality of remote substations. The system comprises a plurality of transceivers in the node station, and a plurality of substation transceivers respectively located in the substations corresponding respectively to the node station transceivers to establish a plurality of pairs of two-way radio links therebetween. The covering area is divided into a plurality of concentric zones, each of the zones being assigned a pair of particular frequencies or a pair of particular polarization planes. Each zone has one or more substations. Transmission power level of each of the node station transceivers and each of the substation transceivers is adjusted so that fine-weather reception field strength at each end of those radio links having a greater length is greater than fine-weather reception field strength at each end of those radio links having a smaller length so that the field strength at each

end of each radio link increases linearly as a function of the length thereof.

With the assignment of different frequency pairs or different polarization-plane pairs to the divided zones and the linearly increasing field strength as a fuction of distance from the transmitter station, the D/U ratio variation can be reduced by a factor of 1/4, which represents a reduction of the minimum azimuth anglular spacing of the substation as viewed from the node sation by a factor of 1/6 to 1/10.

Preferably, the fine-weather reception field strength is given by:

$$RL_k = \frac{ML_k - ML_{(k-1)}}{2} \times \frac{\ell_k - \ell}{\ell_k - \ell_{(k-1)}}$$

where, k = an integer variable including a unity value for identifying the zones;

ℓ = distance between the node station and each of the substations;

ℓ_k = distance from each end of each radio link to a boundary between (k-1)th zone and k-th zone;

$\ell_{(k-1)}$ = a distance from each end of each radio link to a boundary between (k-2)th zone and (k-1)th zone;

RL_k = fine-weather reception field strength measured at distance ℓ_k if transmission power level of each of the two-way radio link is at maximum;

$ML_{(k-1)}$ = difference between the fine-weather reception field strength at distance $\ell_{(k-1)}$ and tolerable rainfall reception field strength thereat; and

ML_k = difference between the fine-weather reception

field strength at distance ℓ_k and tolerable rainfall reception field strength thereat.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be described in further detail with reference to the accompanying drawings, in which:

Fig. 1 is a schematic illustration of a covering area of a radio communications system;

Fig. 2 is a block diagram of the radio communications system; and

Fig. 3 is a graphic representation of the reception field strength characteristic at each substation in comparison with a corresponding characteristic of a prior art system.

DETAILED DESCRIPTION

In Fig. 1, a radio communications system embodying the present invention is schematically illustrated. The system comprises a node station 1 and substations 2a, 2b and 2c within a covering area. The covering area is divided into a central zone 3 and a plurality of concentric ring zones 4. For purpose of simplicity, only two zones are illustrated. Node station 1 is located at the center of central zone 3 and substations 2a and 2b are located in the outer zone 4, but spaced apart a sufficient distance from each other to permit the use of a common frequency pair to establish individual radio links without interference. Substation 2c is located within the center zone 3, but close to the substation 2b. The center zone 3 has a radius ℓ_1 and the outer zone has a radius ℓ_2 twice as greater than radius ℓ_1. Each zone is assigned a pair of particular frequencies, one for the node station and the other for the substations in that zone. In

the illustrated embodiment, two frequenciy pairs f_1 and f_2 are assigned respectively to zones 3 and 4. Node station 1 establishes pairs of two-way radio links respectively to substations 2a and 2b on frequency pair f2 and a pair of two-way radio links to substation 2c on frequency pair f_1. With this per-zone frequency assignment, the desired-to-undesired signal (D/U) ratio of each node-to-substation radio link during precipitation can be reduced to one-half of the worst D/U value of a system which employs a single frequency pair for all zones.

As shown in Fig. 2, node station 1 includes a plurality of transceiver units 1a, 1b and 1c associated respectively with substations 2a, 2b and 2c. Each node station transceiver unit comprises a transmitter 10 which modulates a carrier of a particular frequency with a baseband signal, a span attenuator 11 which couples the output of the transmitter 10 through a duplexer 12 to a parabolic antenna 13. Radio signal received by the antenna 14 is passed through the duplexer 12 to a receiver 14 which it is demodulated to a baseband signal. Node station transceiver units 1a and 1b are assigned transmit frequencies f_2' for establishing radio links with substations 2a and 2c located in the frequency-f_2-zone 4 and node station unit 1c is assigned a frequency f_1' for establishing a radio link with substation 2c located in the frequency-f_1-zone 3. Each of the substations is of identical construction to each transceiver unit of the node station. Substations 2a and 2b are assigned a frequency f_2'' to establish radio links with the transceiver units 1a and 1b of the node station and substation 2c is assigned a frequency f_1'' to establish a link with the transceiver unit 1c of the node station. Frequencies f_1' and f_1'' form a frequency pair for the central zone 3 and frequencies f_2' and f_2'' form another frequency

pair for outer zone 4.

To minimize the variation of the D/U value, the span attenuator 11 at each station is adjusted to give the following relation for the central zone 3:

$$RL = RL_1 - \frac{ML_1}{2} \times \frac{\ell_1 - 1}{\ell_1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

and the following relation for the outer zone 4:

$$RL = RL_2 - \frac{ML_2 - ML_1}{2} \times \frac{\ell_2 - \ell}{\ell_2 - \ell_1} \quad \ldots\ldots\ldots\ldots (2)$$

where, ℓ = length of each radio link;

RL = fine-weather reception field strength measured in dBm at distance ℓ (see Fig. 3);

RL_1 = fine-weather reception field strength measured in dBm at distance ℓ_1 with the transmission power level of each radio link being adjusted to maximum;

RL_2 = fine-weather reception field strength measured in dBm at distance ℓ_2 with the transmission power level of each radio link being adjusted to maximum;

ML_1 = tolerable loss, or a difference between the fine-weather reception field strength and tolerable rainfall reception field strength at distance ℓ_1 from each end of each radio link; and

ML_2 = tolerable loss, or a difference between the fine-weather reception field strength and tolerable rainfall reception field strength at distance ℓ_2 from each end of each link.

Equations 1 and 2 follow a reception field-strength characteristic as indicated at 20 in Fig. 3 which shows that the reception field strength at each substation of the system increases linearly as a function of distance from the node station. The attenuator of each transceiver at the node station 1 is adjusted so that the field strength of the corresponding substation satisfies Equation 1 or 2. In this way, the fine-weather D/U value of a radio link established between the node station and the nearest of the substations in a given zone is likely to suffer most from interference by the farthest substation of the same zone and the rainfall D/U value of a radio link between the node station and the farthest of the substations of a given zone is likely to suffer most from interference by the nearest substation of the same zone. With the field-strength adjustment just described, the D/U value of each radio link from the node to each substation varies in a range one-half the range of D/U variations of the node-to-substation link in the prior art method in which the field strength is usually adjusted at a constant value regardless of the distance from the node station.

The same field-strength adjustment is performed at each substation with respect to its sub-to-node station radio link using the substation span attenuator 11, so that the reception field strength at the node station end of the sub-to-node station link satisfies the linear Equation described above and a similar characteristic to that shown in Fig. 3 can be obtained at the node station with respect to each substation. The D/U value of the sub-to-node station radio link thus varies in a range one-half of the D/U variation range of the corresponding link of the prior art system.

A total variation of the D/U value of the present invention can therefore be reduced to 1/4 of the prior art D/U variation. Since the node-station field strength of a signal from an undesired substation is also determined by the side-lobe sensitivity of an antenna of the node station and since the sensitivity of the antenna is nonlinear as a function of the azimuth angle, the 1/4 reduction of the D/U ratio variation represents a reduction of the minimum azimuth angle between adjacent substations as viewed from the node station by a factor of 1/6 to 1/10 of the prior art minimum azimuth angle. Therefore, the number of substations that can be accommodated in a radio communications system of the type as discussed above can be increased by a factor of 6 to 10.

While mention has been made of an embodiment in which different frequency pairs are assigned to different zones, different polarization planes could equally be as well assigned to different zones.

WHAT IS CLAIMED IS:

1. A radio communications system having a node station centrally located in a covering area and a plurality of remote substations, comprising:

a plurality of node station transceivers in said node station; and

a plurality of substation transceivers respectively located in said substations corresponding respectively to the node station transceivers to establish a plurality of pairs of two-way radio links therebetween, said covering area being divided into a plurality of concentric zones, each of said zones being assigned a pair of particular frequencies or a pair of particular polarization planes, each of said zones having one or more of said substations;

transmission power level of each of said node station transceivers and each of said substation transceivers being adjusted so that fine-weather reception field strength at each end of those radio links having a greater length is greater than fine-weather reception field strength at each end of those links having a smaller length, there being a linear relationship between the fine-weather reception field strength at each end of each said radio link and the length thereof.

2. A radio communication system as claimed in claim 1, wherein said fine-weather reception field strength is given by:

$$RL_k = \frac{ML_k - ML_{(k-1)}}{2} \times \frac{\ell_k - \ell}{\ell_k - \ell_{(k-1)}}$$

where, k = an integer variable including a unity value for

identifying said zones;

ℓ = distance between said node station and each of said substations;

ℓ_k = distance from each end of each said radio link to a boundary between (k-1)th zone and k-th zone;

$\ell_{(k-1)}$ = a distance from each end of each said radio link to a boundary between (k-2)th zone and (k-1)th zone;

RL_k = fine-weather reception field strength measured at distance ℓ_k if transmission power of each of said two-way radio link is at maximum;

$ML_{(k-1)}$ = difference between the fine-weather reception field strength at distance $\ell_{(k-1)}$ and tolerable rainfall reception field strength thereat; and

ML_k = difference between the fine-weather reception field strength at distance ℓ_k and tolerable rainfall reception field strength thereat.

1/2

FIG.1

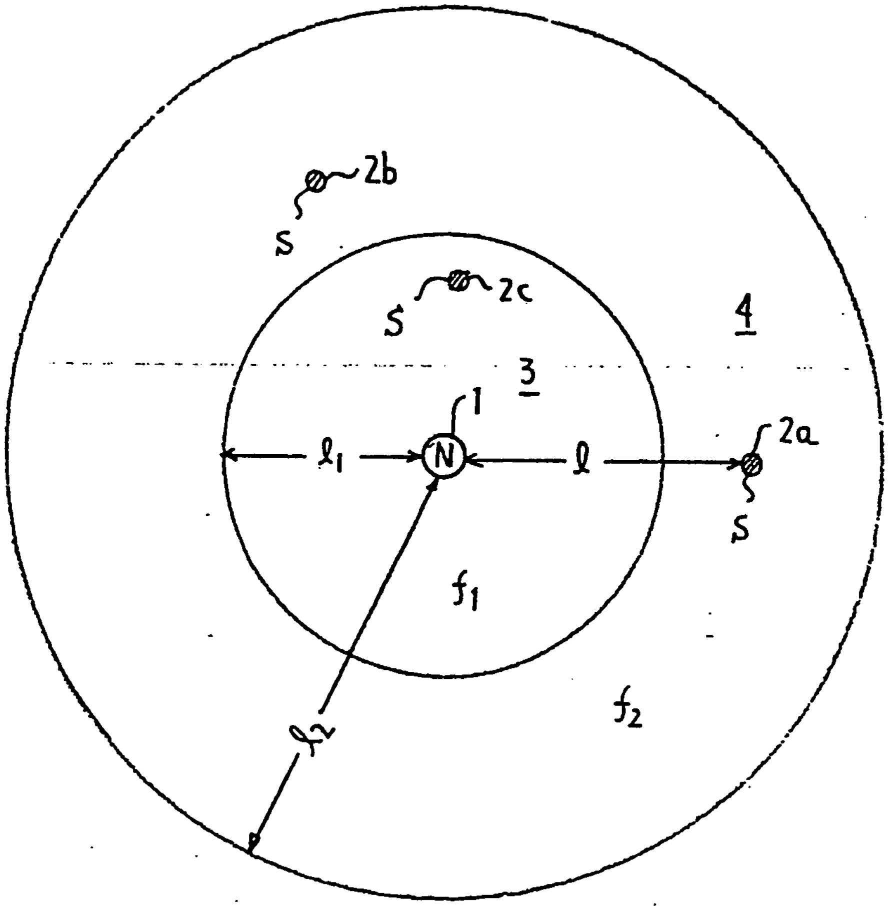
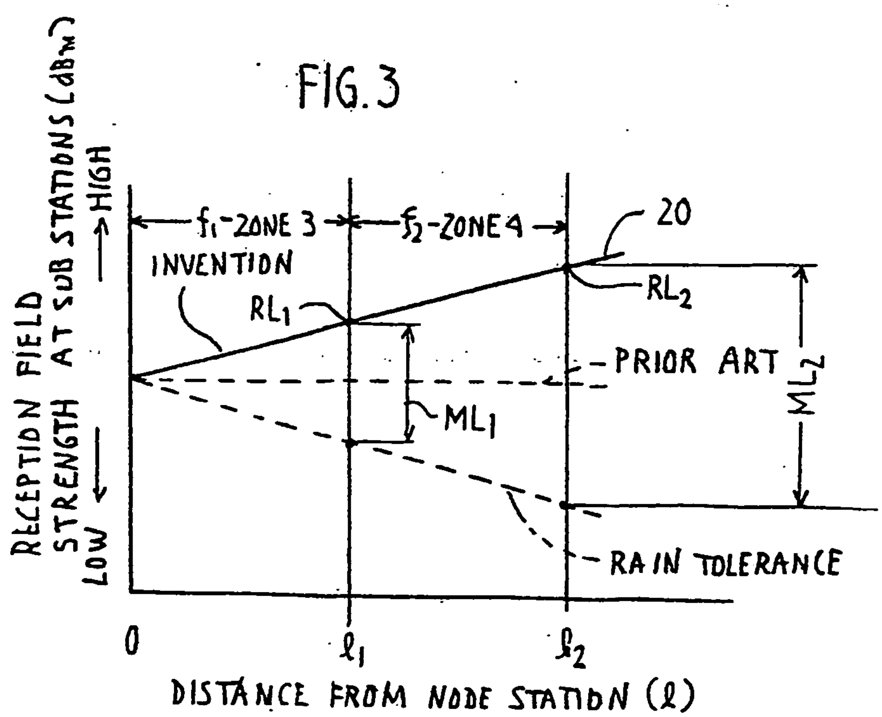

2b
S
2c
S
4
3
1
2a
N
ℓ_1
ℓ
S
f_1
f_2
ℓ_2

FIG.3


RECEPTION FIELD STRENGTH AT SUB STATIONS (dBm)
LOW
HIGH
f_1-ZONE 3
f_2-ZONE 4
20
INVENTION
RL_1
RL_2
PRIOR ART
ML_1
ML_2
RAIN TOLERANCE
0
ℓ_1
ℓ_2
DISTANCE FROM NODE STATION (ℓ)

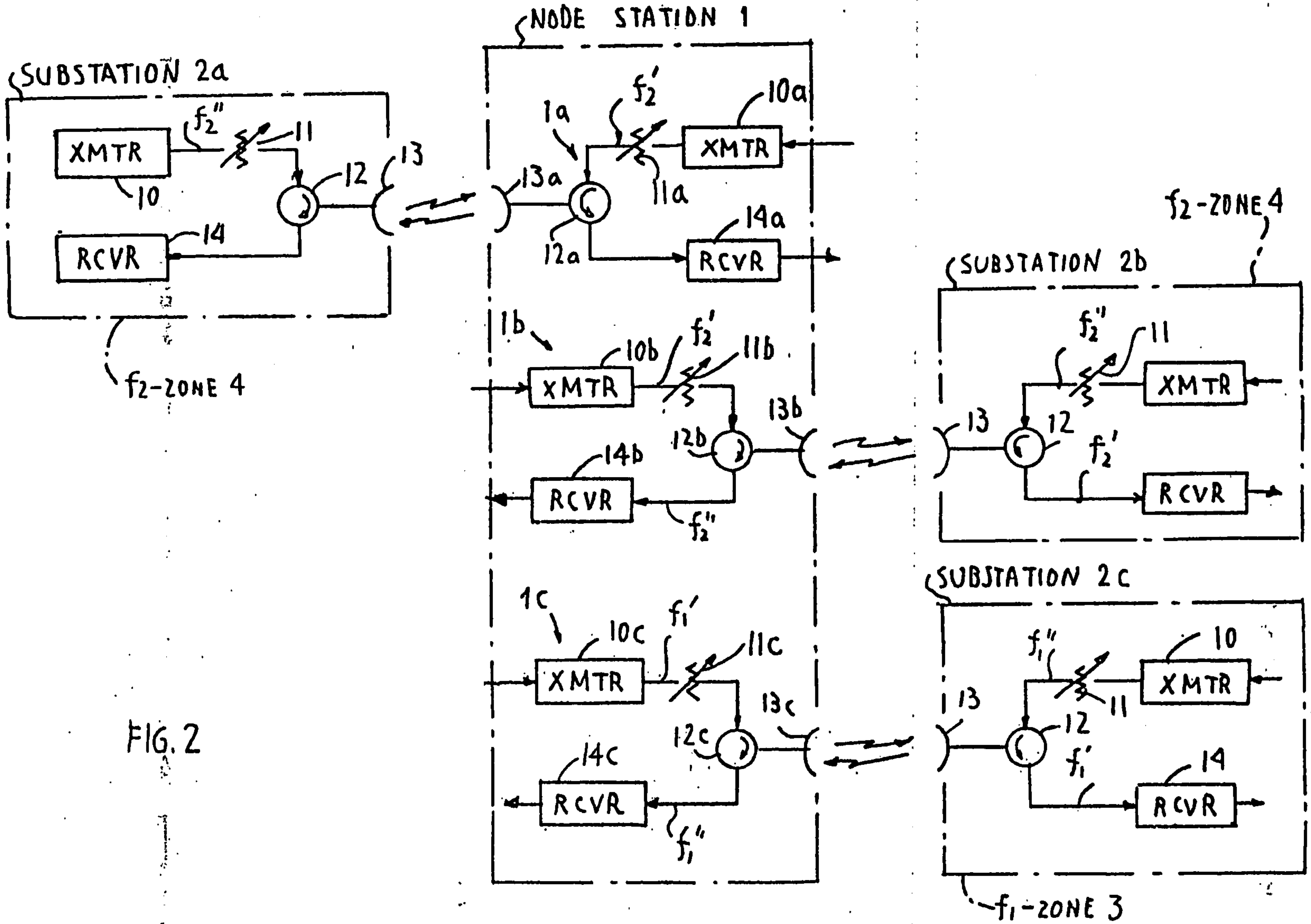

SUBSTATION 2a
XMTR
10
RCVR
14
f_2''
11
12
13
f_2-ZONE 4
NODE STATION 1
1a
f_2'
10a
XMTR
13a
11a
14a
12a
RCVR
1b
10b
f_2'
11b
XMTR
13b
12b
14b
RCVR
f_2''
1c
10c
f_1'
11c
XMTR
13c
12c
14c
RCVR
f_1''
f_2-ZONE 4
SUBSTATION 2b
f_2''
11
XMTR
13
12
f_2'
RCVR
SUBSTATION 2c
f_1''
10
XMTR
13
11
12
f_1'
14
RCVR
f_1-ZONE 3

FIG. 2